Needs and Opportunities to Improve RHC Performance Metrics

Air Source Heat Pumps

NEEP/RTA Renewable H&C Conference

19 June, 2018
Saratoga Springs, NY

Bruce Harley Energy Consulting
My related background/efforts

• Mostly residential
  – Field testing and repair for utility programs and research (CAC, ASHP, GSHP since 1992)
  – RESNET (Home energy rating): GSHP pumping/fan energy documentation and defaults (~2010)
  – Designing/supporting efficiency programs with savings estimates, building science, modeling, training, etc. since 1990
Current Work, Heat Pump Related
BHEC (that’s me)* since 2016:

• Codes and Standards
  – Load based lab test and rating procedure for ASHP: Canadian Standards Association (CSA)

• Consulting to utilities, state & federal agencies
  – Program design, savings estimates, technical evaluation, sizing and installation guidance

• Program implementation
  – Including monitoring / measurement, analysis

• Design review, diagnostics/repair

* Bruce Harley Energy Consulting, LLC
HVAC kWh and Tout (my house)
Resistance Heat, ASHP
Outline

• What explains deviations [WHY]
  – Between ratings and in-field performance?
• What can be done? [WHAT]
  – Reduce deviations
  – Drive [appropriate] market growth
• How can the region work together? [HOW]
  – Support improvements to rating methodologies across RHC technologies
Heat Pump Terms

- CAC: Central air conditioner
- ASHP: Air source heat pump
- GSHP: Ground source heat pump
  - Also known as “geothermal”
- COP: Coefficient of performance, “efficiency”
  = Energy delivered / energy input (like units); 1 = 100%
- HSPF: Heating Season Performance Factor
  = (delivered btu / input watt) \sim (COP \times 3.41)
  - DOE lab test and rating, simplified model
  - 2 outdoor temperatures, one climate, fixed speeds
All models are wrong, but some are useful.

- George Box, famous statistician (1919-2013)
Field Studies – a few highlights

• 1990s, Ecotope (WA):
  – Heat pumps: more energy than resistance heating
  – Big losses in ductwork, other installation issues

• 2003 (Ecotope, ductless heat pumps):
  – 14 electric heat homes retrofitted, 1 zone DHP
  – Saved average of 40% (range was very wide)
Recent Studies

• Building Science Corp (Building America) 2014
  – Long term monitoring in 8 low-energy homes
  – Predictable issues with indoor distribution
  – Big issue with “on/off” (*deep* setback = poor eff.)

• Steven Winter (Building America) 2015:
  – Measured 7 mini-splits retrofitted in homes
  – COP range from 1.1 – 2.3
  – Issues: *low air flow, high inlet temperature, poor integration with central heat*
Recent Studies

• Cadmus 2016 MA/RA impact evaluation:
  – Operating hours much lower than expected (only running 19-27% of the time in winter)
  – Efficiencies somewhat lower than ratings
  – Net result: savings pretty small

• Issues: lack of use (many installed w/AC focus)
  – Need better controls/thermostat placement
  – Multi-zone had lower efficiency

• Cadmus 2017 Vermont
  – Higher utilization, better efficiency and savings
  – Still somewhat below expectations
WHY

...the discrepancies between rated and field performance?
WHY?

• Low utilization
  – People don’t consistently understand heating value
  – Controls often favor central heating in retrofit

• Inflated ratings
  – Test procedures based on decades-old technology

• Internal algorithms not optimal
  – E.g., cycling at above-minimum speeds,
  – Ignored in rating procedures

• Oversizing – especially multi-zone
My Heat Pump

• Before and after firmware adjustment, 2018
  – An example of why this matters
WHAT

... can be done to reduce variations and drive growth?

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WHAT?

• Provide better metrics / ratings
  – To compare systems to each other
  – To assist designers with consistent info

• Craft those metrics to reflect reality
  – Capture/reveal inefficient operating modes
  – Be responsive to climate variations

• Provide consistent signals to marketplace
  – Rewarding good performance in a relevant way
CSA Test Procedure Development

• Working group hosted by CSA, established 2015
• Comprised of Canadian, US members:
  – Canadian utilities (Chair: Gary Hamer – BC Hydro)
  – Natural Resources Canada (NRCan) / CanMet Energy
  – Northwest Energy Efficiency Alliance (NEEA)
  – Pacific Gas and Electric (PG&E)
  – Electric Power Research Institute (EPRI)
• Tasked to develop a CSA “Express Document”
  – Not full ANSI process, but similar – standards language
EXP-07 Development Objectives

• Response to stakeholder needs:
  – Realistic rating for variable speed equipment
  – Seasonal efficiency for heating & cooling reported for a range of climate zones (8 in US/Canada!)
  – Detailed data for hourly computer simulation

• Voluntary test – not intended as regulation
  – Marketplace differentiation of high-performance products
  – E.g. market support via qualified product lists
EXP-07 Scope

- *Single stage, multiple stage, and variable speed heat pumps and air conditioners*
- **Residential** equipment sizes <65,000 Btu/h
- **Ducted/ductless** (including central ducted)
- **Air-to air, single zone**
  - Multi-zone, air-to-water, VRF are planned
- **Use dynamic, load based test rather than fixed speed “test-mode”**

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Stakeholder Needs

• Climate sensitivity
  – For heating and cooling performance
  – Allows for customized “application rating”

• Include standby energy
  – Can be significant in shoulder seasons

• DOE rating: HSPF is not representative
  – Based on two data points and one climate profile
  – Cannot provide accurate heating kWh estimates
  – Meaningful product comparisons impossible
DOE Climate Regions
(only used for heat pump ratings)

Figure 2 Heating Load Hours (HLH_A) for the United States
• Can only use Region IV (pink) to report HSPF
CSA Climate Zone Assignments

Based on data analysis, Building America climates
Conventional (DOE) Heating Test – 2 points extrapolated to wide range of conditions
CSA Test Approach: Multiple points
Match loads with outdoor conditions

![Graph showing building load, aux electric, test points, max heating, and COP vs. Degrees F.](image-url)

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DOE Test: Locked Test Mode

- Fixed fan and compressor speeds
  - High fan speeds, not available in normal operation
  - This increases ratings but not real performance
- Doesn’t include low-load cycling behavior
- Manufacturer’s technicians install equipment and monitor testing using proprietary test modes
  - Can’t be independently duplicated
Dynamic Load Based Testing

• Indoor room has a simulated load
  – Load is “imposed” by indoor room reconditioning equipment, programmed to mimic load
  – Load varies based on outdoor conditions
  – Includes dynamic moisture load for humid/cooling
  – Equipment under test installed per manufacturer’s instruction manual

• On-board controls govern fan, cycling, defrost and latent removal in single test procedure
 CSA Test, Manuf. data, AHRI values

- Test COPs match manufacturer engineering data fairly well
- AHRI shown for illustration purposes
  (From published values at 17/47; not including defrost, $C_D$)
HOW

... can the region work togethe?e?
HOW?

• Support improvements to rating methodologies across RHC technologies
• Support and encourage use of load-based testing, voluntary rating/metrics
Other efforts: NEEP

- Sizing/selection guide and installation guide
- neep.org, “Initiatives/air source heat pumps”, “Air-Source Heat Pump Installer Resources” link on right side
- Also, “Cold Climate Air Source Heat Pump” link at right to cold climate list
- Updates coming in 2018, + consumer’s guide
Sizing and Selecting Guide

Guide To Sizing & Selecting Air-Source Heat Pumps in Cold Climates
A companion to NEEP's Guide to Installing Air-Source Heat Pumps in Cold Climates

Heating (or Heating & Cooling) Displacement

Full Heating System Replacement

Isolated Zone

Application Description

Suggested ASHP System Configuration
(Single/Multi-Zone Ductless, Mini-Duct, Centrally Ducted)

Suggested Treatment of Existing HVAC System

Sizing Strategy Overview

Load Calculation

Equipment Selection Considerations

Oversizing Concerns / Tradeoffs

Further Guidance

One room or zone that is otherwise thermally isolated, a newly finished basement room, build out above garage with poor thermal comfort.
Introduction

High-quality installations of air-source heat pump (ASHP) systems generate referrals, increase sales, reduce callbacks and improve customer comfort and satisfaction. Installation practices also have a major impact on efficiency and performance of an ASHP system. Efficient ASHPs have seen significant sales growth in colder climates in recent years. The recent generation of cold-climate ASHPs, combined with insights from large-scale installation programs and installers, has led to a better understanding of the full range of practices to ensure maximum system performance and customer satisfaction. This guide provides a list of these best practices, as well as homeowner education and system setup guidance, to help ensure efficient air-source heat pumps and happy customers in cold climates.

Heat pumps should always be installed by licensed, trained professionals. Always follow manufacturer’s specification and installation instructions, and all applicable building codes and regulations. All installers should attend a manufacturer’s training or preferred installer program.

ASHPs come in a number of configurations, and in some cases the following guidance may be specific to one or more of those system types. There are many variations and terms used, but these guidelines will focus on the following broad categories: “ductless ASHP” refers to any non-ducted cassette type indoor unit (including wall-mount air handlers, floor mounted consoles, in-ceiling cassettes, etc.); “mini-duct ASHP” refers to remote air handlers that are typically designed for compact, concealed-ceiling or short-duct configurations; and “centrally ducted ASHP” refers to whole-house systems with central air handlers. The icons shown here are used below to indicate when guidance is specific to a certain system type. All items without icons are generally applicable to all ASHP configurations.
## NEEP ccASHP Listings

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Bruce Harley
Bruce Harley Energy Consulting, LLC

bruceharleyenergy@gmail.com

802.694.1719